



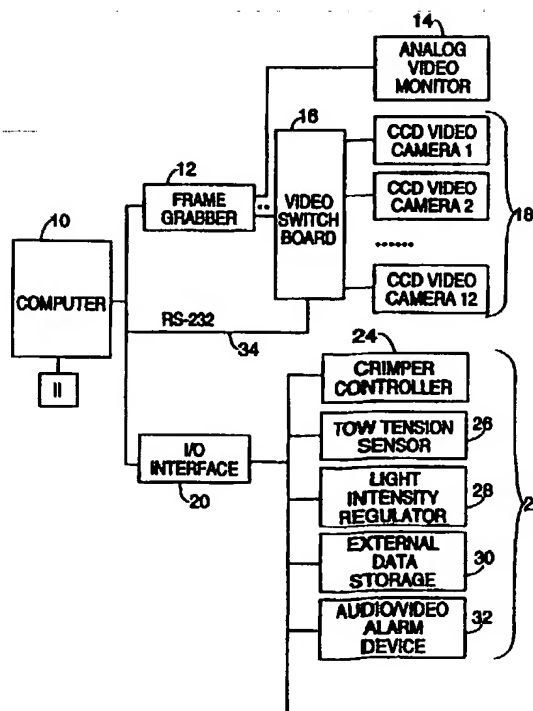
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(54) Title: APPARATUS AND METHOD FOR CHARACTERIZING FIBER CRIMPS

(57) Abstract

Apparatus and method are described for measuring and controlling the crimp characteristics of a moving crimped tow. A light source illuminates a section of the moving crimped tow and at least one camera acquires a video image of the tow. The acquired image is digitized and a processor decomposes the interlaced image into two non-interlaced field images. Crimp characteristics are derived based on the decomposed images.



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APPARATUS AND METHOD FOR CHARACTERIZING FIBER CRIMPS**BACKGROUND OF THE INVENTION****1. Field of the Invention**

5 This invention relates generally to an apparatus and a method for measuring crimp characteristics of fibers; more specifically, an apparatus and method for characterizing fibers in a moving crimped tow.

2. Description of the Prior Art

10 Manufactured or synthetic fiber filaments are usually crimped into a tow before being cut into staple for further processing for various uses such as tops, slivers or yarns. The fibers are usually crimped by passing the fibers through a crimping apparatus to
15 produce waves or crimps. The quality of manufactured fibers is often measured by crimp characteristics such as crimp uniformity, number of crimps per inch, crimp frequency, etc. Until recently, the crimp properties have been measured by manual examination of a cut portion
20 of fiber, for example, by counting the number of crimps per unit length.

 It follows that automated systems for measuring crimp characteristics would greatly improve the speed and accuracy in characterizing the fibers, enabling on line

adjustments in the production process, and the production of fiber staple according to specifications.

Various types of automated systems for measuring crimp characteristics have previously been proposed. Generally, the systems include a light source for illuminating the crimped tow; a photographic element for acquiring an image of a portion of the crimped tow; circuitry for processing the acquired image; and a display for displaying the measured crimp characteristics.

One type of system employs a conventional TV camera to acquire the image of the moving crimped tow. As is apparent to one skilled in the art, a TV camera captures an image pattern and converts the image as electrical charges corresponding to the brightness levels of the moving crimped tow. The charges are converted to a video signal in a sequential order of picture elements. The picture elements are displayed on a monitor as an interlaced raster scan, e.g., the picture elements are swept horizontally from top to bottom. In interlaced scanning, two fields are used.

After completion of the first field scan from top to bottom, the beam is blanked as it returns to the top where the process is repeated to provide a second field scan. Due to the half-line offset for the start of

the beam return to the top of the raster and for the start of the second field, the lines of the second field line lie in between the lines of the first field. Thus, the lines of the two are interlaced. The two interlaced fields constitute a single video frame.

A problem exists with using a conventional TV camera to acquire images of a moving crimped tow. The acquired image is not a true representation of the actual image, because the tow is moving. The two fields which are interlaced are obtained from two different areas of the tow. By the time the beam returns to the top of the raster to start scanning the second field, the tow has moved and a different portion of the tow is scanned. Therefore, measured results derived from the interlaced images depart from the true images.

A common approach used to counteract the above problem associated with the use of a conventional TV camera is by use of a synchronized strobing system. A stroboscopic light source emits a light pulse which creates an apparent stopped motion view of the moving crimped tow. The camera is synchronized to take a snap shot of the moving crimped tow when the light pulse is emitted. A synchronized strobing system effectively freezes the moving crimped tow and the two interlaced fields do not produce an erroneous image as in using a

non-strobed system. However, advanced electronics are required for the synchronization controls. Further, in order to cover an entire width of the moving tow when using a synchronized strobing system, movement of the focused strobe light source and/or the camera may be necessary, and positioning mechanisms such as stepping motors and controls are involved. If light or camera movement is required, extra time is needed to position the devices, making on-line or real-time measurements and/or device adjustments difficult if not impossible. Examples of strobed-based apparatus for measuring crimp characteristics of fibers in a moving crimped tow are disclosed in U.S. Patent Nos. 4,737,846; 4,415,926; 4,232,336; and 4,240,110.

A need therefore exists for an apparatus which uses a continuous or non-strobed system for acquiring images of a moving crimped tow which is devoid of the above problems and is also capable of on-line or real-time measurements and/or system adjustments.

SUMMARY OF THE INVENTION

The present invention relates to an apparatus and method for measuring crimp characteristics of fibers in a moving crimped tow where a camera is used to acquire a video image of the moving crimped tow. A continuous

light source illuminates the crimped tow while the camera acquires the image. A processor and its associated software decomposes the acquired interlaced image into two non-interlaced images.

5 The processor and the stored software converts the two non-interlaced images into a series of horizontal bands. The bands are analyzed to measure the crimp characteristics of the section of moving crimped tow represented by the bands. The measured results may be
10 displayed and adjustments be made to peripheral devices which in turn control the manufacturing process to correct deviations from the operator-specified specifications. The processor and stored programs processes the decomposed image into user defined
15 categories and the frequency of the crimps belonging in each category is displayed on a monitor for allowing the operator to determine whether the crimped tow is within the pre-determined specifications.

20 A method of the invention includes the steps of acquiring a video image of a crimped tow; digitizing the acquired image; decomposing the digitized image into two field images; and processing the two field images.

25 An illustrative approach according to the present invention in the step of processing the two field images includes dividing one of the images into a series

of horizontal bands; constructing an intensity profile by averaging the pixel intensity of each band; identifying local minima and maxima of the intensity profile, and labeling a maximum as a crimp peak if the difference in intensity between the maximum and its two immediate neighboring minima exceeds an operator-specified intensity threshold value; calculating and storing the distance of neighboring crimp peaks for all peaks identified in the above step; and grouping the crimp peaks into a crimp type category.

A preferred method further includes the step of communicating measurement results to a plurality of peripheral devices which configure the manufacturing process of the crimped tow.

Advantageously, the apparatus and method of the present invention also provide convenient and reliable means for monitoring the quality of a crimped tow to obtain physical data therefrom which can be used as a quality control measure during the manufacturing process. For a traditional batch-type manufacturing process, the system also supports a start-up mode process for minimizing production waste.

BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the invention is described hereinbelow with reference to the drawings wherein:

5 FIG. 1 is a block diagram of the major components for measuring fiber crimp characteristics according to a preferred embodiment of the present invention.

10 FIG. 2 is a flow chart illustration of a method of measuring the fiber crimp characteristics according to the present invention.

FIG. 3 is a flow chart illustration of a start-up mode process.

FIG. 4 is a flow chart illustration of a "check illumination" method.

15 FIG. 5 is a flow chart illustration of a "normal crimp measurement" method.

20 FIGS. 6a and 6b are illustrative monitor displays of representative crimp criteria and system settings for a preferred crimp measurement apparatus for a manual and an automatic operating mode, respectively, according to the present invention.

FIGS. 7a, 7b, 7c, 7d and 7e are illustrative setting displays for the automatic operating mode.

25 FIGS. 8 and 9 are screen depictions showing illustrative crimp measurement results in text and in graphs.

FIG. 10 shows a display of illustrative alarm events.
FIGS. 11a, 11b, 11c, and 11d are screen depictions
showing illustrative analog and digital I/O test
diagnostics for the illustrative crimp measurement system
according to the present invention.

Appendix A lists a representative portion of
the stored program including program for implementing the
method as outlined in FIG. 2.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

An illustrative crimp measurement system of the
present invention is a digital image analysis based
system for characterizing fiber crimps including
quantifying the number of crimps per unit length and
crimp size distribution of a moving crimped tow. The
measurement, which is non-contact and non-destructive,
can be conducted off-line or on-line during the yarn
manufacturing process at which a crimped tow moves at
high speeds, for example, around 1,200 feet per minute.

Referring to FIG. 1, the illustrative crimp
measurement system according to the present invention
includes a computer 10, a frame grabber 12, an analog
video monitor 14, a video signal switch board 16, a
plurality of video cameras 18, an I/O interface 20, and
peripheral devices 22. The peripheral devices 22

include, but are not limited to, a crimper controller 24, a tow tension sensor 26, a light intensity regulator 28, an external data storage 30, and an audio/video alarm device 32.

5 The video signal switch board 16 may be interfaced to the computer 10 by a RS-232 cable 34, and the plurality of video cameras 18 for directing a video signal to the computer 10 from the plurality of video cameras 18 mounted at different positions across a tow or
10 at different tow stretch lines. The I/O interface 20 is connected to the peripheral devices 22 for I/O communication between the computer 10 and peripheral devices 22. The frame grabber 12 is connected to the analog video monitor 14 and the video signal switch board
15 16 for digitizing analog signals and directing the digital data to the computer 10.

 The computer 10 is preferably an IBM compatible PC which includes a Pentium-type microprocessor and operates in Microsoft Windows environment. The computer
20 10 includes software in the form of stored program 11 for controlling the hardware components of the system. The video signal switch board 16 is preferably a KNOX VIDEO RS 12x2 model capable of accommodating up to 12 video cameras. Through computer 10, an operator sends signals
25 via RS-232 cable 34 to the video switch board 16 to

selectively receive video signal from one of cameras 18. The selection process may be by a multiplexing scheme commonly used by one skilled in the art. The I/O interface 20 constitutes two data acquisition boards, preferably a CyberResearch DAS 1601 and a CYRDDA 06, for I/O communications between the computer 10 and the peripheral devices 22. The frame grabber is preferably a Truevision TARGA+64 digitizer capable of digitizing a video image into a two-dimensional array of data.

The video cameras 18 are preferably Panasonic Model GP-MF502 cameras with electronic shutter speed control. The image acquired by camera 18 is similar to images acquired by conventional video cameras, an interlaced image, i.e., a composition of two (e.g. even and odd) field images. As previously explained, due to the tow's movement, each field image may represent a different area of the crimped tow.

User interfaces include a main control panel, a display of measurement results on the computer screen, a keyboard or a mouse, and selection icons on the computer display for allowing an operator to configure the crimp measurement system, as discussed further below.

A light source (not shown) is positioned proximate the plurality of video cameras 18 for continuously illuminating the moving crimped tow. The

light source is preferably a halogen flood light lamp having intensity adequate to cover the full width of a tow line. The intensity of the light source may be adjusted by light intensity regulator 28 which in turn is under control by processor 10 and stored program 11. At least one tow stretch line (not shown) is positioned below the light source for moving the crimped tow. The illustrative components of Fig. 1 may characterize three or more tow lines. The tow stretch line may be stationary but preferably moves the crimped tow at speeds up to around 1,200 feet per minute.

FIG. 2 illustrates an algorithmic process of stored program 11 for measuring the crimp characteristics of the moving crimped tow. Under software control, the moving tow is continuously illuminated by the light source. Video cameras 18 are preferably stationary and may be enabled for continually capturing images of the stationary or moving crimped tow, and signals representing selected images from one of cameras 18 are received by the computer 10 upon selection by video switch board 16 under control by stored program 11.

The selected image is digitized by the frame grabber 12 and may be stored in computer 10 in step 100. In step 105, the 'grabbed' image is decomposed into its pre-interlaced even- and odd-field images. The

decomposition process is preferably performed by an image-decomposition module of stored program 11, as illustratively shown in Table 1.

Field_Decompose Function

```

5  input      -      memory pointer of input image whose height is 400 and width 512
   output[2]  -      two memory pointers of output images
   field=0    -      field ID number, 0 for even field and 1 for odd field

Loop:
  For RowIndex=1 to 400 Step 1
10  memory(output [field],input 512) - copy image row data from input image to output image
   output[field]=output[field]+512 - advance memory pointer of output image to next row
   input=input+512                 - advance memory pointer of input image to next row
   If field=0 Then
15     field=1
   Else
     field=0
   End If
Next Row Index

```

Table 1

20 The field decompose function defines a loop which processes each of the 400 lines of digitized data constituting a video frame. The processed lines are separated into first and second or odd and even fields depending on the RowIndex count. For example, row 400 is

25 separated from the video frame and designated as part of the even-field, when the field identification number in line 4 of Table 1 is set to 0. The steps in the loop are repeated until all 400 lines are separated into an odd or even field.

A representative portion of stored program 11 including program codes for implementing the process as described in FIG. 2 is shown in Appendix A.

Noise-reduction of the decomposed images by conventional image noise-reduction techniques such as the use of a filter is performed in step 110. This process is optional and may be disabled by the operator via the setting displays of FIGS. 6a and 6b.

Upon decomposition, each odd and even field will have 200 lines. For purposes of measuring crimp characteristics, the lines in each odd and even image are divided into M bands, each band having N lines. In the present example, M is set at 50 and N at four. Thus, each decomposed image has 200 lines, 50 bands with four lines in each band.

In step 115 each band is averaged to form an intensity profile, which is represented in a gray level scale ranging from 0 (black) to 255 (white). Step 120 locates all local maxima and minima crimp peaks of the intensity profile based on the operator-specified crimp intensity threshold. A crimp peak is labeled as a maximum if the difference in its intensity and the intensity of its two immediate neighboring crimp peaks exceed an operator-specified intensity threshold value. The crimp intensity threshold value is adjusted with a

web material-related optical factor which takes into consideration the absorption and reflection qualities of the web material.

5 The crimp intensity threshold is entered into the system via a crimp measurement setting display, such as shown in FIG. 6a. The crimp intensity threshold in FIG. 6a has been set to eight.

10 The frequency of adjacent maxima crimp peaks is calculated in step 125, where frequency is defined as the reciprocal of the distance between two adjacent maxima. In step 130 each maxima is identified as a valid crimp if its corresponding frequency is within a user-specified range.

15 Each crimp is grouped into one of the three pre-defined categories, which include micro, normal and large. The grouping is determined based on an operator-specified CPI range for each of the three categories via one of the system measurement setting displays depicted by FIGS. 6a and 6b. As an example, in FIGS. 6a and 6b a
20 crimp is categorized as micro, normal or large if the CPI parameter is greater or equal to 16, 8, or 4, respectively.

25 Statistical analysis is performed on the measured results to determine parameters such as average CPI and the percent of area covered by crimps categorized

in each category. The statistical analysis is displayed on the computer screen to enable the operator to view the data as further discussed below.

Steps 115 to 130 are repeated for each band until all image lines of one decomposed image have been analyzed (135). Then, steps 115 to 130 are performed in analyzing the crimp characteristics of the second non-interlaced image (140).

To capture images representing the entire width of the crimped tow, which is usually about four inches or more, more than one camera may be used. In the present illustrative embodiment, three cameras are used for each tow line. The same steps 100 to 140 of FIG. 2 are followed in analyzing the images acquired by the other cameras to obtain the crimp statistics for the entire width of the moving crimped tow. The data from all the three cameras is averaged to get the overall crimp measurement results. These results along with other statistical analysis results are displayed on the computer screen for allowing the operator to examine the crimp characteristics of the crimped tow.

FIGS. 8 and 9 are exemplary screen depictions of crimp measurement results. FIG. 8 indicates that the average CPI is 9.8 for the overall tow, and 22.6, 11.2, and 6.2 for the crimps categorized in the micro, normal

and large categories, respectively. FIG. 8 further indicates that the percentage of tow area covered by measurable crimp is 69.8%, and that 3.0%, 40.5%, and 26.3% of the area is covered by crimp categorized in the micro, normal and large categories, respectively. The screen depiction of FIG. 8 further includes a main user interface control panel on the right side for controlling the crimp measurement system and setting system parameters.

FIG. 9 indicates the online crimp distribution statistics for a crimped tow. These distribution statistics change as the crimp measurement process proceeds to enable the operator to continuously monitor the crimp measurements of the moving crimped tow. The online crimp distribution screen also indicates the moving crimp average (mAvg), the percent of area covered by crimp in each of the three categories and the overall area covered by crimp, along with other data.

The operator in viewing the measured results can direct peripheral devices 22 via I/O interface 20 to take appropriate actions to conform the manufacturing process of the crimped tow to the proper product and process specifications. As an example, the operator can instruct crimper controller 24 to increase or decrease the amount of crimps or to reconfigure the manufacturing

process to reallocate the number of crimps categorized as micro, normal and large, depending on the contemplated use of the crimped tow.

With reference to system measurement setting displays depicted by FIGS. 6a and 6b, the operator can select either manual or automatic as the operating mode, as shown on the top left-hand side of FIGS. 6a and 6b. In FIG. 6a the manual operating mode is selected and in FIG. 6b the automatic operating mode has been selected.

Other initial settings or adjustments for the crimp measurement system can be made with the aid of setting displays depicted by FIGS. 6a-6b. For example, parameter adjustments or settings can be made for image resolution, band size, crimp intensity threshold, valid crimp per inch (CPI) range, overall CPI set point, CPI tolerance; tow stretch line select and camera select; crimp types and specifications; and image pre-process configuration.

On the bottom left-hand side of FIGS. 6a and 6b, the operator can select whether to apply smoothing to the acquired image before it is processed. If smoothing is selected then each odd and even image is passed through a filter to perform a noise-reduction of the image as discussed above. The amount of image lines which constitute a band is also selected in the same box labeled "Image Pre-process." In FIG. 6a the selected

band size is eight and in FIG. 6b the selected band size is four.

In the system measurement setting display depicted by FIG. 6b in which the automatic mode has been selected, the number of tow stretch lines which have been selected for measurement is three. The number of cameras which have been selected for each tow stretch line is also three. Directly below the selections for the number of tow stretch lines and cameras for each tow stretch line is a user interface for accessing the system setting displays depicted by FIGS. 7a-7e for the automatic operating mode.

By selecting the square marked "General" the General Setting for Automatic Mode setting display depicted by FIG. 7a is accessed. This setting display allows the operator to set the general system setting and various parameters, such as the sampling rate, the number of images which are kept on the screen, the number of moving average data points, the image resolution, the tow tension adjustment factor, the crimp intensity threshold, the fiber optical adjustment factor, the average image intensity, the tolerance factor, and the no tow image intensity.

By selecting the square marked "Alias" in FIG. 6b, the Common Name setting display depicted by FIG. 7b

is accessed. This setting display allows the operator to provide a short and long name for each tow stretch line and for each camera positioned across the width of the tow stretch lines. As shown by FIG. 7b, the short and long common names for the tow stretch lines are 0, 1, and 2 and ts800, ts801, and ts802, respectively. The short and long common names for the three cameras are R, C, and L and right, center, and left, respectively.

By selecting the square marked "Trend" in FIG. 6b, the Trend Window Setting display depicted by FIG. 7c is accessed. This setting display allows the operator to select the parameters he desires to be displayed during normal measurement. The selected parameters are displayed on an on-line crimp trend window, such as the one depicted by FIG. 9. Using the Trend Window Setting display, the operator can set the ranges for the overall CPI parameter, percent of area covered by overall CPI, and percent of area covered by crimp in the micro, normal, and large categories.

By selecting the square marked "I/O" in FIG. 6b, the I/O Usage Setting display depicted by FIG. 7d is accessed. The display of FIG. 7d allows the operator to manually enable and disable each tow stretch line, the start-up process, the bad-tow alarm, the specifications alarm, the illumination, the tow tension, and set the

range for the overall CPI and other parameters. On the right-hand side of FIG. 7d, the operator can enable the system malfunction alarm and run either a digital or analog diagnostic test for each data acquisition board.

5 By selecting the square marked "Start Up" in FIG. 6b, the Start-Up Setting display depicted by FIG. 7e is accessed. This display allows the operator to configure a start-up mode process, another advantageous feature of the apparatus which is described below.

10 Through FIG. 7e the operator can set the image resolution, band size, the crimp intensity threshold value, the minimum measurable area, the range for valid crimp, and other start-up mode process parameters.

The start-up mode process is shown by FIG. 3. 15 The start-up mode process is particularly advantageous when used with batch-type fiber processing, i.e., the staple fibers are provided in batches and are usually discontinuous after certain lengths. The fiber characteristics of the beginning portion of each batch is usually "uncharacteristic" or different than the rest of 20 the batch. This is mostly due to loose ends from cutting and other deformities. The uncharacteristic beginning portions are usually cut and discarded.

25 The start-up mode is used to monitor the beginning portions of each batch and to alert the

operator when the crimped tow reaches the
"characteristic" portion of the batch, upon which the
operator cuts and discards the beginning
"uncharacteristic" portion. The start-up process reduces
5 wastage due to unnecessarily discarding too long of a
beginning portion and provides more uniform
characteristics in each batch. The start-up mode also
prevents the possible corruption of data from preventing
the inclusion of measurements of the crimp
10 characteristics of the beginning of the crimped tow with
the main portion of the tow. The start-up mode activates
an alarm when the good-tow is positioned in direct view
of at least one camera 18 set-up for imaging the width of
the moving crimped tow.

15 Referring to FIG. 3, the crimp measurement
system is activated by turning on the continuous light
source (300a); setting the stretch line identification
and turning on the bad-tow alarm light (300b) to signify
the start of a batch; selecting a start-up video channel
20 (300c) which may be a separate camera specifically
situated to capture start-up images; setting the good-tow
and aborting the time counters (300d); and preparing the
trend window (300e).

25 An abort time counter is used to set a time
within which to complete the start-up process. The

counter is updated (305) and it is checked to determine if it has reached the pre-set abort time (310). Upon reaching the abort time, the start-up mode is terminated. The illumination is turned off (315a), the bad-tow alarm light is turned off (315b), and normal measurement is resumed (315c).

Within the abort time, images of the moving crimped tow are acquired using the start-up camera (320). The acquired images are displayed on the screen (325). The crimp per inch (CPI) parameter is measured and recorded (330), and the trend window is updated (335).

The illumination is checked by computer 10 to determine if the average image intensity is within the specifications (340). If the illumination does not meet the operator specifications, it is adjusted by increasing or decreasing the voltage to the continuous light source to increase or decrease the image intensity (405). If the voltage to the light source is exceeded (410), a system alarm is checked (415) and an alarm is activated in the following steps. An alarm/event message is displayed on the computer screen (420) for indicating to the operator of illumination or other system problems. A screen depicting an alarm/event message window is shown by FIG. 13.

A system alarm light may be turned on (430) if a system alarm I/O has been enabled as determined by step (425). The system alarm I/O is enabled through the system setting display depicted by FIG. 7d.

5 If the illumination does meet the operator specifications, the process returns to step 345 of FIG. 3. In step 345 the software checks to determine whether the measured area of the crimped tow is within the operator specifications. If not, the process returns to
10 step 305 and the abort-time counter is updated. If in step 345 the software determines that the measured area of the crimped tow is within the operator specifications, the uncharacteristic beginning portion of the tow has likely moved through the system.

15 In step 350, stored program 11 checks to determine whether the CPI parameter of the crimped tow is within the operator specifications. If the CPI parameter is within the operator specifications, the good-tow counter is updated (355). The good-tow counter is
20 checked to determine whether the good-tow count has been reached (360). If the good-tow counter has reached the good-tow count, the process returns to step 315 to terminate the start-up mode feature. The start-up mode feature is terminated by turning off the illumination
25 (315a); turning off the bad-tow alarm light to indicate

to the operator that the good-tow has been reached
(315b); and resuming with normal crimp characteristics
measurements (315c).

5 If in step 350 the CPI parameter is not within
the operator specifications, the good-tow counter is
reset (365) and the start-up process returns to step 305
where the abort time counter is updated. Similarly, if
the good-tow count has not been reached, the process
returns to step 305. The start-up process continues
10 until the CPI parameter in step 350 is determined to be
within the operator specifications and the good-tow count
has been reached in step 360.

The interaction between the software, the
hardware components, and the status checks during the
15 normal measurement mode is illustrated by the flow chart
of FIG. 5. Steps 500 and 505 determine whether the
start-up trigger has been triggered in order to toggle
over to the start-up process mode depicted by the flow
chart of FIG. 3. If the start-up trigger has been
20 triggered, such as in the case of batch-type processing,
normal measurement is postponed and the system proceeds
with the start-up process.

In normal measurement mode, computer 10 and
associated program 11 determine whether camera 18 is
25 enabled to acquire images of the moving crimped tow. The

system preferably uses three cameras positioned across the width of the moving crimped tow for imaging the entire width. If one of the three cameras is disabled or has malfunctioned, measurements may continue with the other cameras. According to a preferred embodiment of the invention, three different tow stretch lines can be running at the same time with three cameras positioned across the width of each tow.

The number of tow stretch lines to be measured in the automatic operating mode is set by the setting display depicted by FIG. 6b. Stored program 11 checks the cameras 18 and the cutter before selected images are acquired. For example, when a camera 18 is enabled (515), and the cutter I/O is not enabled or the cutter is running (steps 520 and 525), an image is acquired for processing from the selected camera (step 530).

It is noted that although three cameras are chosen in the present embodiment, measurements of crimp characteristics may be made with images acquired from less than three cameras. In some instances, the operator may disable one of the three cameras. For crimp measurements and for illumination control, average intensity of images from all enabled cameras are used.

If in step 515 the camera is not enabled, the next video channel is selected in step 535 and an image

of the moving crimped tow from the selected camera of the video channel is received by processor 10 and stored program 11 (Step 540). If the image has not been received, the process returns to step 515.

5 The acquired image is displayed on the image window (545); the CPI is measured, displayed and logged (550); and the moving average is calculated (555). The measured results may be compared to the operator specifications (560) and the specifications status is
10 checked (565), the message window is updated (570) and a flag may be set to note that the specifications status has changed (575).

 If the specifications status has not changed or after the flag is set to note that the specifications
15 status has changed (580), stored program 11 checks whether all enabled cameras of a tow line have been selected to forward an image of the moving crimped tow. If not, the process 515 to 580 repeats for the next camera. After all enabled cameras have forwarded an
20 image, the process checks the illumination based on the average image intensity of the acquired images from the three cameras and if necessary, makes adjustments to the illumination control (steps 585, 590 and 595. See also Fig. 4).

The crimp measurements are also based on averages of images from the three cameras. For example, if CPI output I/O is enabled (step 605), the average CPI is output and may be displayed (step 605). In step 610
5 stored program 11 checks whether the measured specifications of the crimp characteristics have changed from the previous measurement and update the trend window accordingly in step 615 to enable the operator to view the measured on-line crimp characteristics and other
10 measured parameters. Alarms may be used to alert the operator if the measurements are outside of pre-set specification.

The process of Fig. 5 repeats for other tow lines.

15 Advantageously, the use of a continuous wave (cw) light source for illuminating the moving crimped tow and conventional TV cameras obviates the need to move the light source or camera by stepper-motor controls. The crimp characteristic measurements can be displayed at
20 near real-time speed as compared to systems which use stepper motor controls. In the latter systems, the updating of the measurement results is much slower due to the time necessary for positioning the lighting and cameras. Consequently, system parameter adjustments are

proportionately delayed in systems having motorized positioning controls.

The stored program 11 further provides means for checking the data acquisition boards by executing diagnostic tests as indicated by the screens of FIGS. 11a-11d. These screens allow the operator, for example, to set the bit/channel positions, channel identification, and control the input and output.

It will be understood that various modifications can be made to the embodiment of the present invention herein disclosed without departing from the spirit thereof. The above description should not be construed as limiting the invention but merely as exemplifications of preferred embodiments thereof. Those skilled in the art will envision other modifications within the scope and spirit of the present invention as defined by the claims appended hereto.

WHAT IS CLAIMED IS:

1. A system for measuring crimp characteristics of fibers in a moving crimped tow, said system comprising:

a processor and associated stored program;

5 illuminating means positioned over said moving crimped tow for illuminating a section of said moving crimped tow;

at least one camera for capturing at least one interlaced video image of said section of said moving crimped tow;

10 digitizing means for digitizing said at least one interlaced video image into digital data;

decomposing means for decomposing said digital data into decomposed data representing first and second non-interlaced field images, wherein said processor and associated stored program processes said decomposed data; and

15 a display for displaying crimp characteristics based on said processing of said decomposed data.

2. The system according to claim 1, wherein said decomposing means includes means for dividing said first and second field images into a series of horizontal bands and for establishing an intensity profile of each of said bands by
20 averaging pixel intensity of sequential horizontal lines within each of said bands.

3. The system according to claim 1, wherein said processor processes said decomposed data as minima and maxima intensity profiles wherein a maxima is labeled as a crimp peak if difference in intensity between said maxima

- 30 -

and its two neighboring minima exceeds an operator-specified intensity threshold value.

4. The system according to claim 1, wherein said processor calculates distances of neighboring crimp peaks, compares said distances with
- 5 operator-specified thresholds, groups said crimp peaks into one of a micro, normal or large categories, and tabulates overall crimp statistics for said first field image.

5. The system according to claim 1, wherein said processor communicates measurement results to at least one of a plurality of peripheral devices for configuring said system depending on predetermined specifications.

- 10 6. The system according to claim 1, including a plurality of cameras for substantially covering a full width of said moving crimped tow.

7. The system according to claim 6, wherein said processor and stored program control a video switch board for selectively receiving signals from one of said plurality of cameras.

- 15 8. The system according to claim 1, wherein said illuminating means is a continuous-wave light source.

9. The system according to claim 8, wherein said illuminating means illuminates at least a full width of said moving crimped tow.

10. A method for measuring crimp characteristics of fibers in a
- 20 moving crimped tow, said method comprising the steps of:

- a) illuminating said crimped tow with a continuous wave light source;
- b) acquiring an interlaced video image of the crimped tow;

c) digitizing the video image;

d) decomposing the digitized image into two non-interlaced

field images;

e) processing said two field images; and

5

f) displaying crimp characteristics based on said processed

images.

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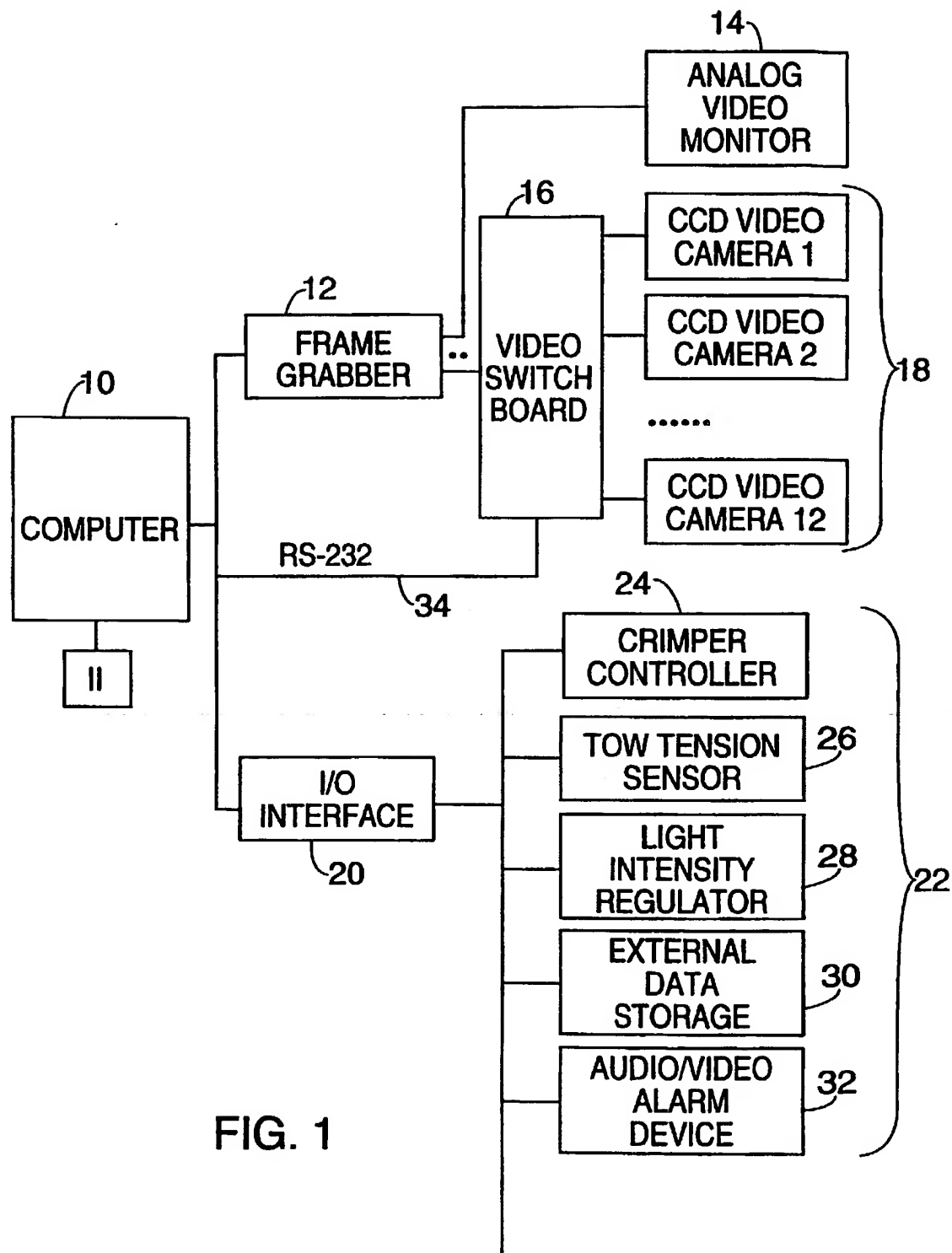


FIG. 1

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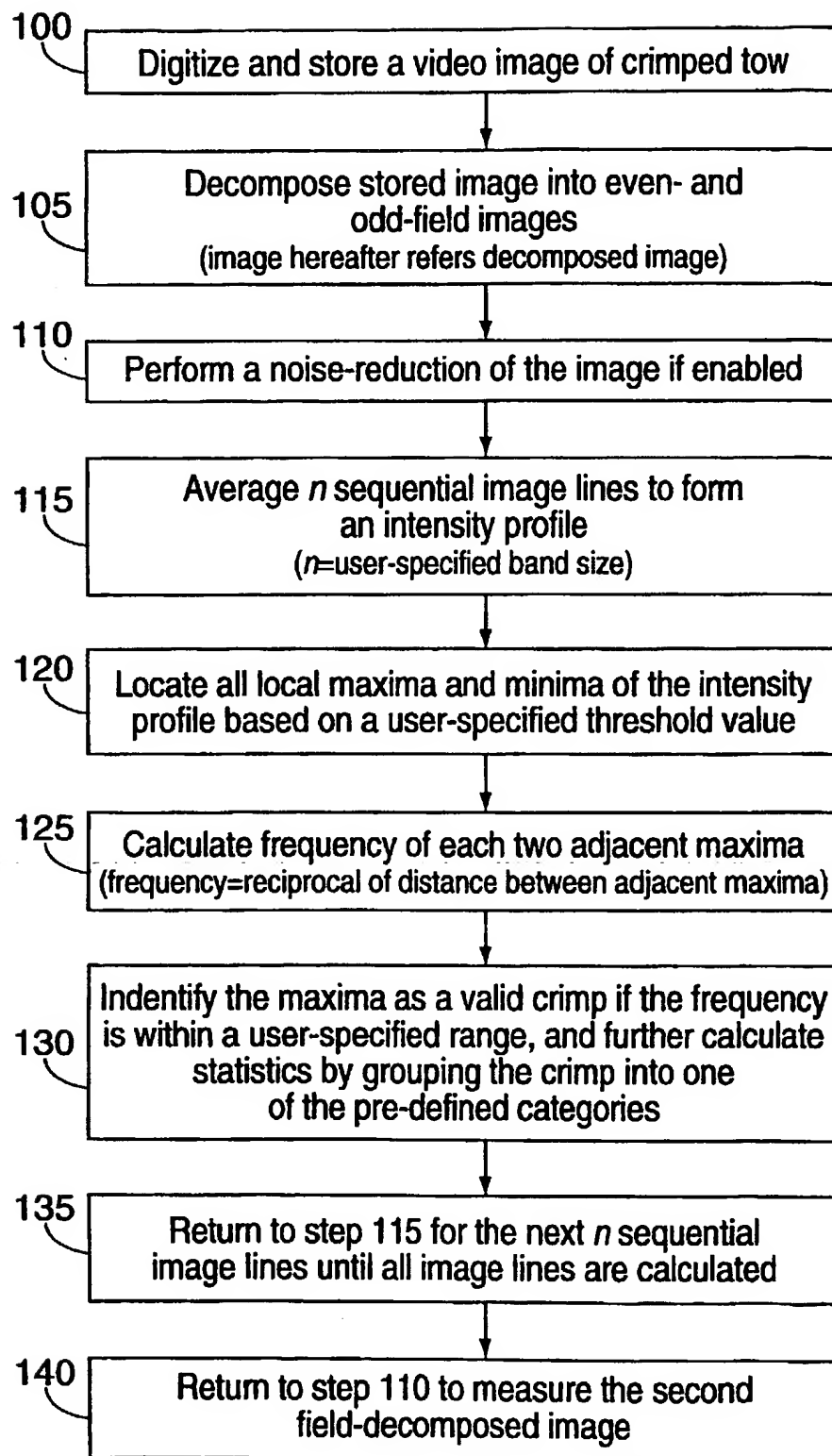


FIG. 2

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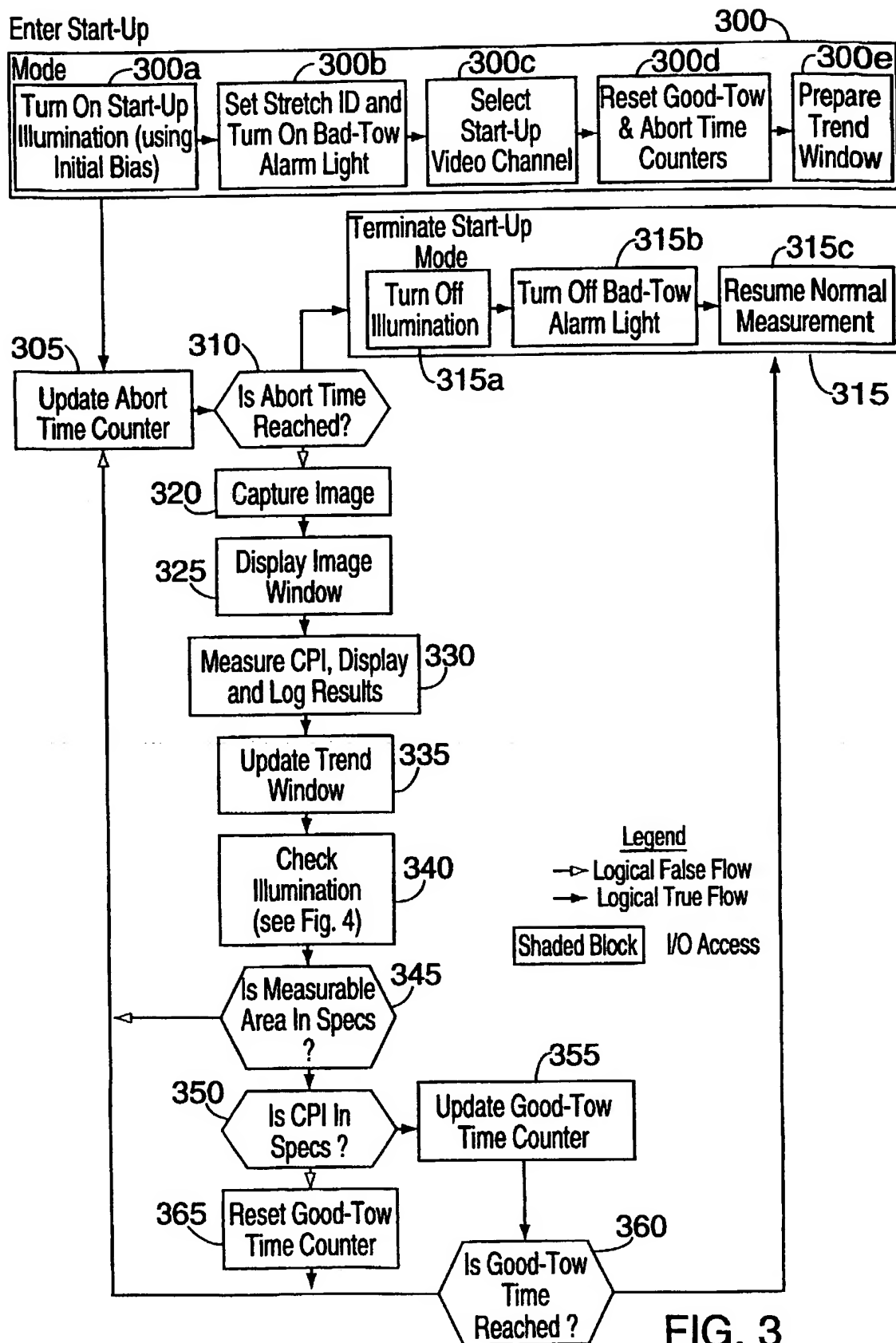


FIG. 3

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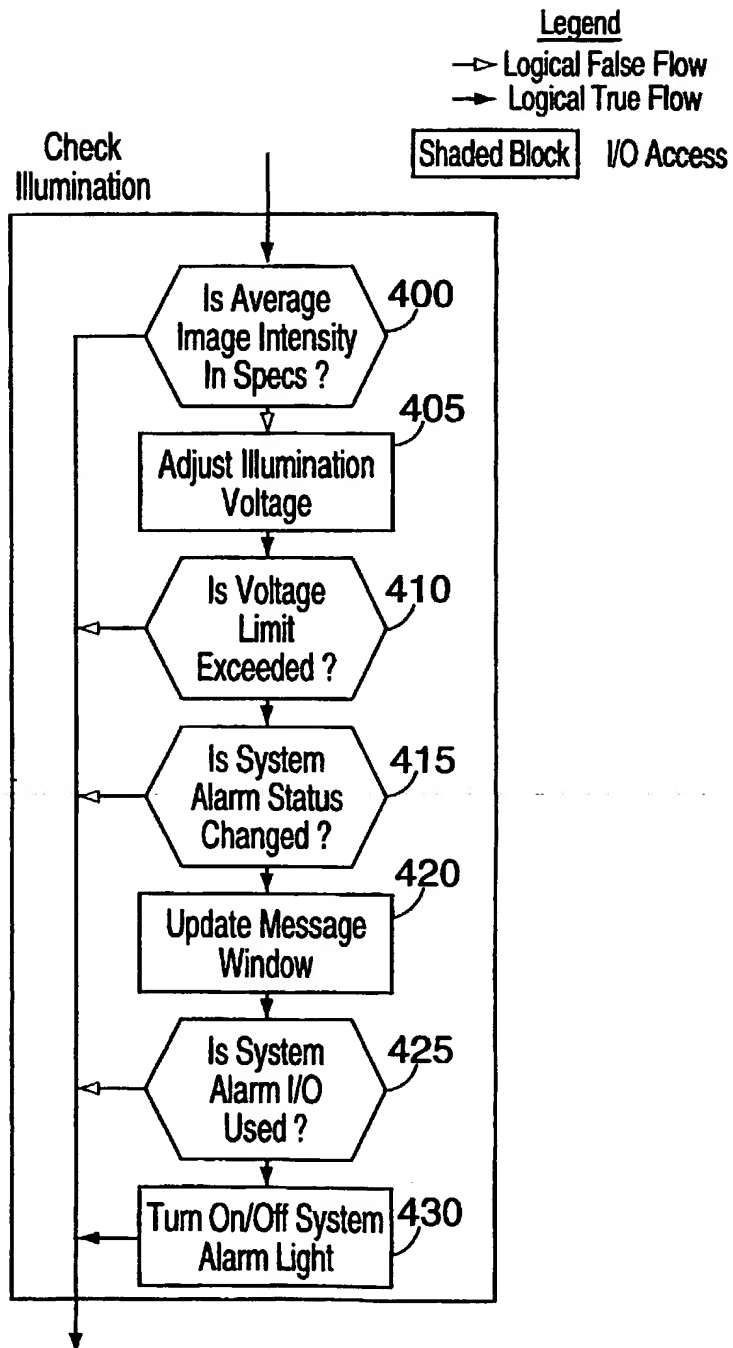


FIG. 4

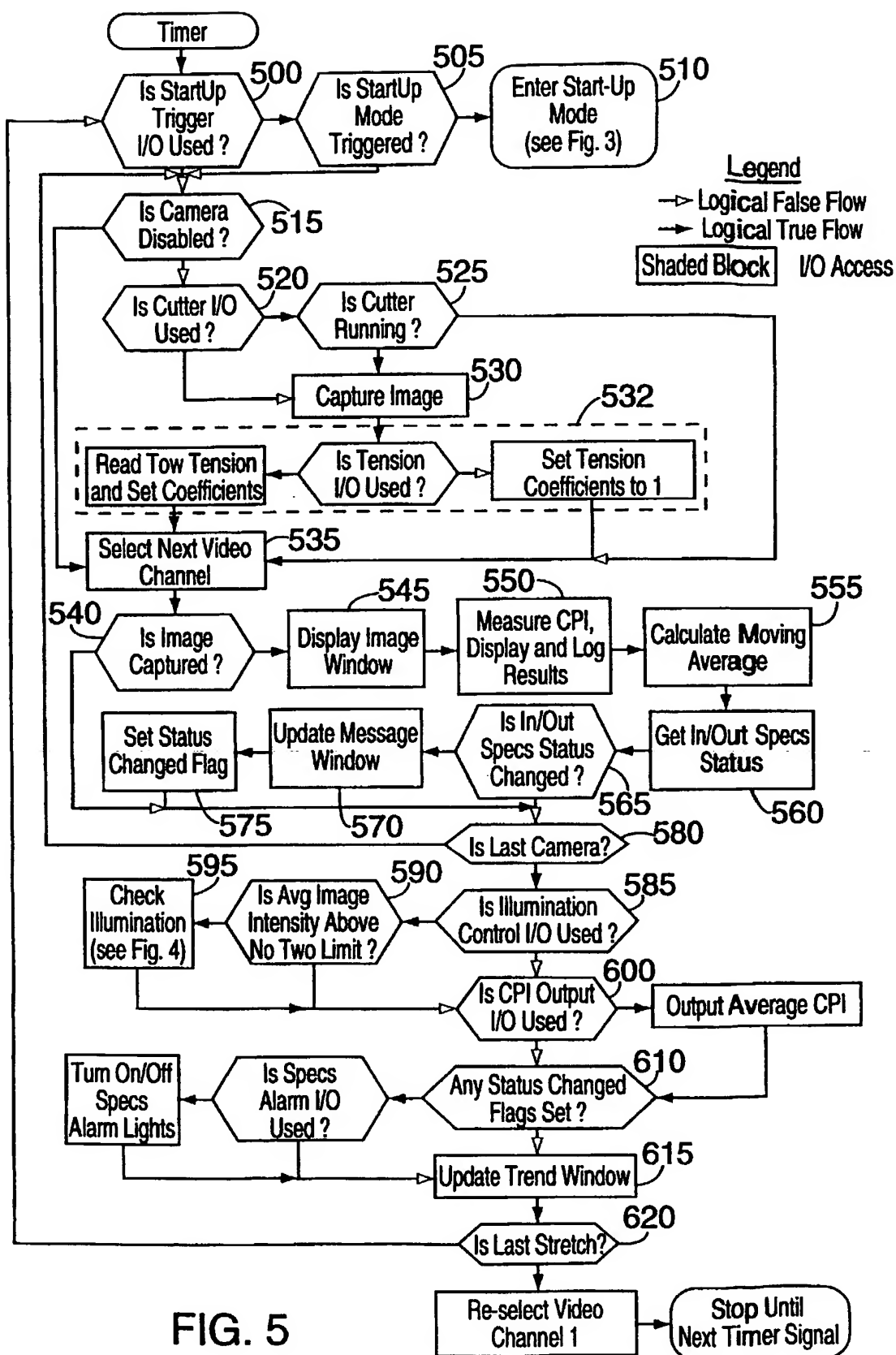


FIG. 5

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Crimp Measurement Setting																
Operating Mode <input checked="" type="radio"/> Manual <input type="radio"/> Automatic																
Crimp Intensity Threshold <input type="text" value="8"/> Image Resolution <input type="text" value="170"/> Video Channel (0=As Is) <input type="text" value="0"/> Even/Odd Field Decompose <input type="checkbox"/>																
Image Pre-process Apply Smoothing <input checked="" type="checkbox"/> X <input type="text" value="3"/> Y <input type="text" value="1"/> Band Size <input type="text" value="8"/> Show Banded Image <input type="checkbox"/>																
Crimp Type & Specification Stretch ID <input type="text" value="0"/> All Same <input type="checkbox"/> <table> <tr> <th>Type</th> <th>If CPI >=</th> <th>% Area Limit</th> </tr> <tr> <td>None</td> <td><input type="text" value="30"/> <</td> <td><input type="text" value="30.0"/></td> </tr> <tr> <td>Micro</td> <td><input type="text" value="16"/> <</td> <td><input type="text" value="15.0"/></td> </tr> <tr> <td>Normal</td> <td><input type="text" value="8"/> ></td> <td><input type="text" value="40.0"/></td> </tr> <tr> <td>Large</td> <td><input type="text" value="4"/> <</td> <td><input type="text" value="15.0"/></td> </tr> </table> Overall CPI Set Point <input type="text" value="11.0"/> CPI Tolerance (+/-) <input type="text" value="2.0"/>		Type	If CPI >=	% Area Limit	None	<input type="text" value="30"/> <	<input type="text" value="30.0"/>	Micro	<input type="text" value="16"/> <	<input type="text" value="15.0"/>	Normal	<input type="text" value="8"/> >	<input type="text" value="40.0"/>	Large	<input type="text" value="4"/> <	<input type="text" value="15.0"/>
Type	If CPI >=	% Area Limit														
None	<input type="text" value="30"/> <	<input type="text" value="30.0"/>														
Micro	<input type="text" value="16"/> <	<input type="text" value="15.0"/>														
Normal	<input type="text" value="8"/> >	<input type="text" value="40.0"/>														
Large	<input type="text" value="4"/> <	<input type="text" value="15.0"/>														
<input checked="" type="checkbox"/> Data Log <input type="text" value="File Name..."/> <input type="text" value="c:\cia\crimp.log"/> Rate: log 1 point every <input type="text" value="1"/>																
<input type="button" value="Print"/> <input type="button" value="Save..."/> <input type="button" value="Load..."/> <input type="button" value="OK"/> <input type="button" value="Cancel"/>																

Measurement Setting For Manual Mode

FIG. 6A

Crimp Measurement Setting																
Operating Mode <input type="radio"/> Manual <input checked="" type="radio"/> Automatic																
# of Stretch Lines <input type="text" value="3"/> # of Camera/Stretch <input type="text" value="3"/> <div> <input type="button" value="General"/> <input type="button" value="Alias"/> </div> <div> <input type="button" value="Trend"/> <input type="button" value="I/Q"/> <input type="button" value="Start Up"/> </div>																
Image Pre-process Apply Smoothing <input checked="" type="checkbox"/> X <input type="text" value="5"/> Y <input type="text" value="1"/> Band Size <input type="text" value="4"/> Show Banded Image <input type="checkbox"/>																
Crimp Type & Specification Stretch ID <input type="text" value="0"/> All Same <input type="checkbox"/> <table> <tr> <th>Type</th> <th>If CPI >=</th> <th>% Area Limit</th> </tr> <tr> <td>None</td> <td><input type="text" value="30"/> <</td> <td><input type="text" value="30.0"/></td> </tr> <tr> <td>Micro</td> <td><input type="text" value="16"/> <</td> <td><input type="text" value="15.0"/></td> </tr> <tr> <td>Normal</td> <td><input type="text" value="8"/> ></td> <td><input type="text" value="40.0"/></td> </tr> <tr> <td>Large</td> <td><input type="text" value="4"/> <</td> <td><input type="text" value="15.0"/></td> </tr> </table> Overall CPI Set Point <input type="text" value="11.0"/> CPI Tolerance (+/-) <input type="text" value="2.0"/>		Type	If CPI >=	% Area Limit	None	<input type="text" value="30"/> <	<input type="text" value="30.0"/>	Micro	<input type="text" value="16"/> <	<input type="text" value="15.0"/>	Normal	<input type="text" value="8"/> >	<input type="text" value="40.0"/>	Large	<input type="text" value="4"/> <	<input type="text" value="15.0"/>
Type	If CPI >=	% Area Limit														
None	<input type="text" value="30"/> <	<input type="text" value="30.0"/>														
Micro	<input type="text" value="16"/> <	<input type="text" value="15.0"/>														
Normal	<input type="text" value="8"/> >	<input type="text" value="40.0"/>														
Large	<input type="text" value="4"/> <	<input type="text" value="15.0"/>														
<input checked="" type="checkbox"/> Data Log <input type="text" value="File Name..."/> <input type="text" value="c:\cia\crimp.\$??"/> Rate: log 1 point every <input type="text" value="1"/>																
<input type="button" value="Print"/> <input type="button" value="Save..."/> <input type="button" value="Load..."/> <input type="button" value="OK"/> <input type="button" value="Cancel"/>																

Measurement Setting For Automatic Mode

FIG. 6B

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General Setting for Automatic Mode	
General Power-On Auto Start <input type="checkbox"/> Power-Outage Message Backup <input checked="" type="checkbox"/> Image Even/Odd Field Decompose <input checked="" type="checkbox"/> Fix Image Window Position <input checked="" type="checkbox"/> Close All Image Windows When Start <input checked="" type="checkbox"/> Sampling Rate (min) <input type="text" value="10.00"/> # Images Kept on Screen <input type="text" value="10"/> # Moving Avg Data Points <input type="text" value="20"/>	Stretch Line Specific Stretch ID <input type="text" value="0"/> All Same <input type="checkbox"/> Image Resolution <input type="text" value="150"/> Tow Tension Adjustment <input type="text" value="1.00"/> Crimp Intensity Threshold <input type="text" value="8"/> Fiber Optical Adjustment <input type="text" value="1.00"/> Average Image Intensity <input type="text" value="150"/> Tolerance (+/-) <input type="text" value="5"/> No Tow Image Intensity < <input type="text" value="0"/> Disable Cameras: 0 <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/>
Video Multiplexer Com Port <input type="text" value="COM1"/> Output <input type="text" value="2"/> Baud Rate <input type="text" value="9600"/>	
<input type="button" value="Close"/>	

'General' for Automatic Mode

FIG. 7A

Common Name		
Items	Short Name (1 char.)	Long Name (5 char.)
Stretch 0	<input type="text" value="0"/>	<input type="text" value="ts800"/>
1	<input type="text" value="1"/>	<input type="text" value="ts801"/>
2	<input type="text" value="2"/>	<input type="text" value="ts802"/>
Camera 0	<input type="text" value="R"/>	<input type="text" value="right"/>
1	<input type="text" value="C"/>	<input type="text" value="center"/>
2	<input type="text" value="L"/>	<input type="text" value="left"/>
<input type="button" value="Close"/>		

'Alias' for Automatic Mode

FIG. 7B

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Trend Window Setting			
User-Defined Trend			
Setting ID <input type="text" value="0"/>			
ITEMS	Min	Max	
1. 00-CPI	<input type="text" value="5"/>	<input type="text" value="15"/>	
2. 00-%AM	<input type="text" value="5"/>	<input type="text" value="15"/>	
3. 00-%AN	<input type="text" value="5"/>	<input type="text" value="40"/>	
4. <not used>	<input type="text" value="5"/>	<input type="text" value="60"/>	
5. <not used>	<input type="text" value="5"/>	<input type="text" value="60"/>	
6. <not used>	<input type="text" value="5"/>	<input type="text" value="60"/>	
Stretch/Camera Specific			
Stretch ID <input type="text" value="0"/>		All Same <input type="checkbox"/>	
Camera ID <input type="text" value="0"/>		All Same <input type="checkbox"/>	
ITEMS	Min	Max	
OverAll CPI	<input type="text" value="9"/>	<input type="text" value="13"/>	
%A OA CPI	<input type="text" value="0"/>	<input type="text" value="100"/>	
%A Micro	<input type="text" value="0"/>	<input type="text" value="20"/>	
%A Normal	<input type="text" value="0"/>	<input type="text" value="100"/>	
%A Large	<input type="text" value="0"/>	<input type="text" value="20"/>	
Close			

'Trend' for Automatic Mode

FIG. 7C

I/O USAGE SETTING			
Control Item	Stretch 0	Stretch 1	Stretch 2
Cutter On/Off : DIN, Bit ID	<input type="text" value="1"/>	<input type="text" value="3"/>	<input type="text" value="5"/>
Reverse Logic	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Start-Up : Trigger, DIN, Bit ID	<input type="text" value="2"/>	<input type="text" value="4"/>	<input type="text" value="6"/>
Stretch ID/Power, DOUT, Bit ID	<input type="text" value="2"/>	<input type="text" value="5"/>	<input type="text" value="8"/>
Bad Tow Alarm, DOUT, Bit ID	<input type="text" value="3"/>	<input type="text" value="6"/>	<input type="text" value="9"/>
Specs Alarm: DOUT, Bit ID	<input type="text" value="4"/>	<input type="text" value="7"/>	<input type="text" value="10"/>
Overall CPI: AOUT, Chan. ID	<input type="text" value="1"/>	<input type="text" value="3"/>	<input type="text" value="5"/>
Low	<input type="text" value="4"/>	<input type="text" value="4"/>	<input type="text" value="4"/>
Range	<input type="text" value="16"/>	<input type="text" value="16"/>	<input type="text" value="16"/>
Illumination: AOUT, Chan. ID	<input type="text" value="2"/>	<input type="text" value="4"/>	<input type="text" value="6"/>
Initial Bias (0-4095)	<input type="text" value="4095"/>	<input type="text" value="4095"/>	<input type="text" value="4095"/>
Correction Coefficient	<input type="text" value="10.0"/>	<input type="text" value="10.0"/>	<input type="text" value="10.0"/>
Tow Tension: AIN, Chan. ID	<input type="text" value="1"/>	<input type="text" value="2"/>	<input type="text" value="3"/>
# of Readings	<input type="text" value="6"/>	<input type="text" value="6"/>	<input type="text" value="6"/>
Gain	<input type="text" value="1"/>	<input type="text" value="1"/>	<input type="text" value="1"/>
System Malfunction Alarm			
DOUT, Bit ID <input type="text" value="1"/>			
DAS1600 Board Configuration			
AIN Mode <input type="text" value="bipolar"/>			
AIN Config <input type="text" value="Single-ended"/>			
AOUT 1 Mode <input type="text" value="bipolar"/>			
AOUT 2 Mode <input type="text" value="bipolar"/>			
AOUT 1 Ref.V <input type="text" value="5.00"/>			
AOUT 2 Ref.V <input type="text" value="5.00"/>			
Digital Test		Analog Test	
DDA-06 Board Configuration			
Base Address (Hex) <input type="text" value="330"/>			
Detection Port ID <input type="text" value="none"/>			
Digital Test		Analog Test	
Default Bit/Channel Assignment			
Set Bit/Channel ID to 0 if I/O not to be used			
Close			

'I/O' for Automatic Mode

FIG. 7D

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Start-Up Setting	
Image Resolution	150
Min Duration In-Specs (sec)	5
Band Size	4
Time Out (sec)	20
Crimp Intensity Threshold	4
Illumination Control	
Min Measurable Area (%)	40
via AOUT #1 on DAS1600 board	
Valid Crimp (CPI)	Min 4
Average Image Intensity	120
Max	30
Tolerance (+/-)	10
Average CPI Set Point	10.0
AOUT Initial Bias (0-4095)	4095
CPI Tolerance (+/-)	0.5
Correction Coefficient	10.0
Close	

'Start Up' for Automatic Mode

FIG. 7E

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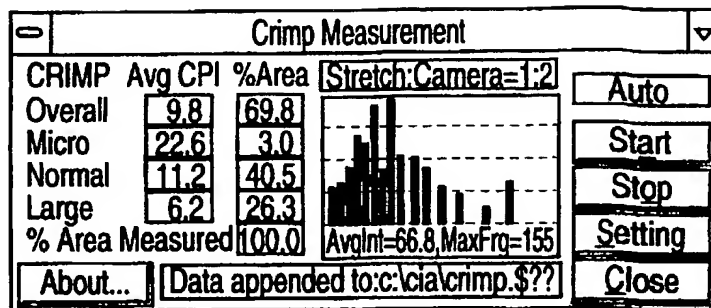


FIG. 8

Main Control Panel And Measurement Results Of The Current Image

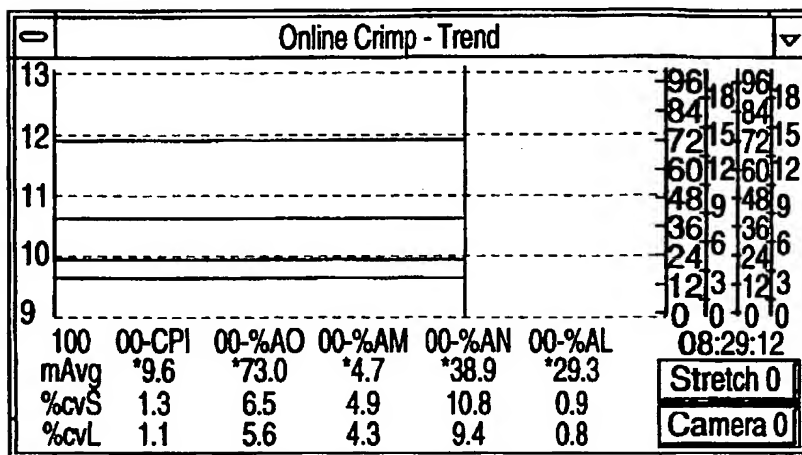


FIG. 9

Trend Window of Moving Average

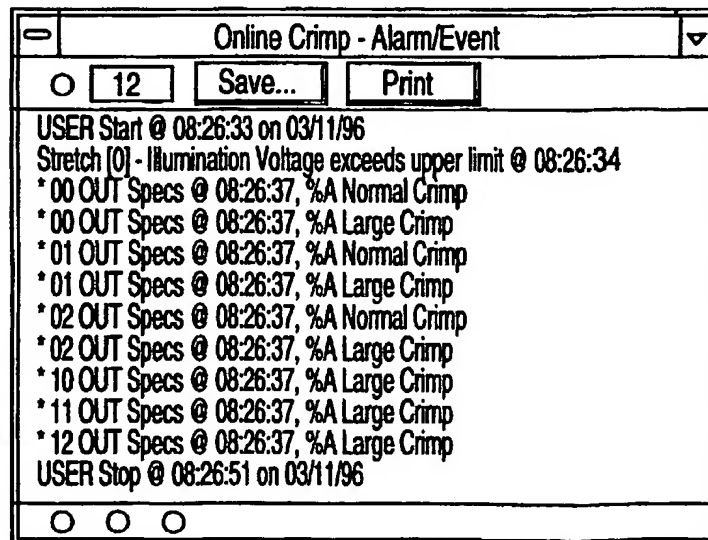


FIG. 10

Alarm/Event Message Window

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DAS1600 Board Digital I/O Test																							
Bit / Channel Position																							
16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	In	In	In	In	In	In	In	In
×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	1	1	1	1	1	1	1	1
Output Control										Input Control										Close			
Reset All		Set All		Get Input		Start		Stop		Get Input		Start		Stop									

'Digital Test' for I/O Usage Setting

FIG. 11A

DAS1600 Analog I/O Test	
Channel ID	Input: 1
Gain	1
Voltage	0.000
	Get Input
	Start
	Stop
	Output: 1
	Output
	Close

FIG. 11B

'Analog Test' for I/O Usage Setting

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DDA-06 Board Digital I/O Test																							
Bit / Channel Position																							
8	7	6	5	4	3	2	1	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
0	0	0	0	0	0	0	0	0	In	In	In	In	In	In	In	In	In	In	In	In	In	In	In
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Output Control								Input Control															
<input type="button" value="Reset All"/>		<input type="button" value="Set All"/>		<input type="button" value="Get Input"/>		<input type="button" value="Start"/>		<input type="button" value="Stop"/>		<input type="button" value="Close"/>													

'Digital Test' for I/O Usage Setting

FIG. 11C

DDA-06 Analog I/O Test	
Channel ID	<input type="text" value="1"/> <input type="button" value="Output"/>
Setting	<input type="text" value="0 to 5V"/> <input type="button" value="1"/>
Raw Count	<input type="text" value="0"/> <input type="button" value="1"/>
Voltage	<input type="text" value="0.000"/> <input type="button" value="Close"/>

FIG. 11D

'Analog Test' for I/O Usage Setting

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 97/06411

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 G01B11/30 G01N21/89 D02G1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 92 02001 A (E.I. DU PONT DE NEMOURS) 6 February 1992 see abstract see page 2, line 12 - line 27 see page 6, line 4 - line 7 see page 7, line 10 - line 18 see page 8, line 24 - page 11, line 2 see page 12, line 14 - line 22 see figures 1-3	1-10
Y	US 4 698 674 A (BLOOM) 6 October 1987 see abstract see column 1, line 14 - line 24 see column 1, line 56 - column 2, line 5 see figure 1	1-10
	-/-	

☒ Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search

14 August 1997

Date of mailing of the international search report

21/08/1997

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Thomas, R.M.

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 97/06411

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 675 730 A (ADOMAITIS) 23 June 1987 see column 2, line 41 - line 60 see column 4, line 8 - line 16; figures -----	6-9

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 97/06411

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9202001 A	06-02-92	AU 649465 B AU 8291891 A CA 2087040 A EP 0539499 A JP 5509136 T US 5351308 A	26-05-94 18-02-92 17-01-92 05-05-93 16-12-93 27-09-94
US 4698674 A	06-10-87	NONE	
US 4675730 A	23-06-87	EP 0284630 A	05-10-88